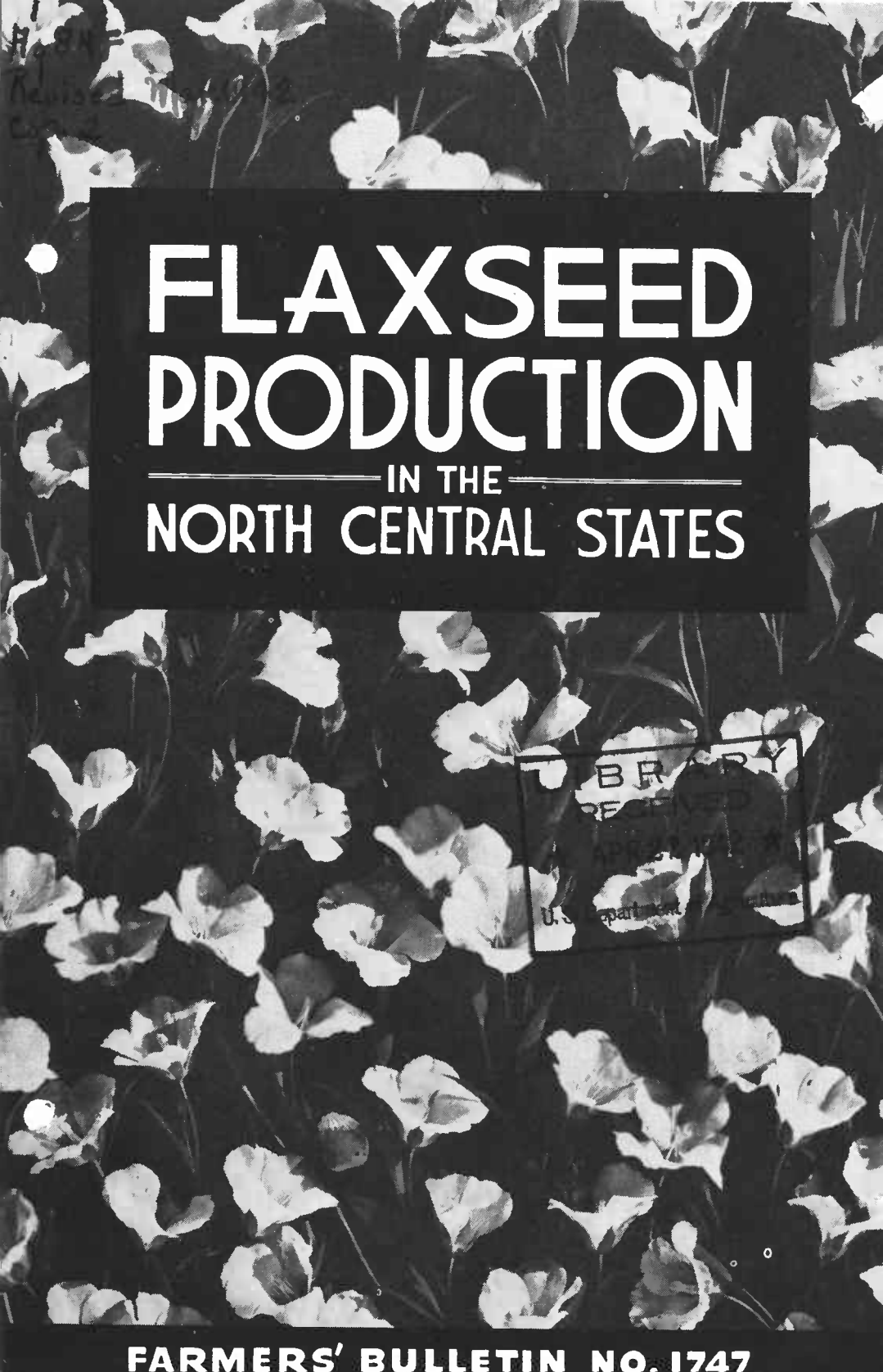

FLAXSEED PRODUCTION IN THE NORTH CENTRAL STATES

FARMERS' BULLETIN NO. 1747

FLAX IS GROWN both for fiber and for flaxseed, or linseed. It is the purpose of this bulletin to give information in regard to the production of flaxseed in the North Central States, where the crop is grown most extensively. Formerly flax was grown chiefly on new lands, but with the development of wilt-resistant varieties it is now possible to grow it frequently on the same land in short-time rotations with other crops.

It is important that flax be grown on clean land. Flax does well following corn that has been given thoroughly clean cultivation. A rotation that includes a small grain and a legume crop, such as sweetclover, red clover, soybeans, or field peas, followed by corn and finally by flax, is very satisfactory.

Flax is primarily a cool-climate crop. As a general rule, therefore, it should be sown early, as it is benefited by the cooler growing season of early summer.

Bison flax is the leading commercial variety. It is remarkably resistant to flax wilt, and its medium-large seeds yield a high percentage of oil.

Flax for seed production is sown at the rate of fully 3 pecks (42 pounds) an acre in Minnesota, but at a somewhat lower rate in the drier western part of the flax-producing area. A good stand of flax helps to control the growth of weeds.

This bulletin is a revision of and supersedes Farmers' Bulletin 1328, Production of Seed Flax.

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FLAXSEED PRODUCTION IN THE NORTH CENTRAL STATES [1]

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Contents

INTRODUCTION

THE FLAX PLANT (*Linum usitatissimum*) is the source of two valuable products, flaxseed and fiber. In practice, however, distinct types or varieties of flax are grown, depending on whether the seed or the fiber is the principal product desired. This bulletin treats of growing the crop only for the seed, from which linseed oil is made. The coarse straw of seed flax, as usually grown, does not yield a fiber suitable for spinning.

Flax is an annual plant that grows to a height of 12 to 40 inches. It has a distinct main stem and a short taproot. The slender root branches, however, may extend to a depth of 3 to 4 feet in light soil. In thick seeding, as for fiber flax, only the main stem develops, whereas in thin stands two or more branches may arise from the base of the plant. The flax flower has 5 petals and a 5-celled boll or capsule, which when filled contains 10 seeds but not more than 10 except in abnormal double bolls.

Normally, flax is self-pollinated, and very little natural crossing occurs. The flowers open at sunrise on clear warm days, and the petals fall before noon. The petals are blue, pale blue, white, or pale pink in different varieties. The seeds usually are light brown, although in certain varieties they are yellow, mottled, greenish yellow, or nearly black.

Flaxseed yields from 32 to 44 percent of oil, based on dry weight. In commercial crushing about 19 pounds, or 2½ gallons, of oil are obtained from a bushel (56 pounds) of seed. A part of the oil, 3 to

[1] Cooperative investigations carried on by the Bureau of Plant Industry, U. S. Department of Agriculture, and the North Dakota Agricultural Experiment Station. For information regarding growing flax as a fall-sown crop, see Farmers' Bulletin 1793, Flaxseed Production in the Far Western States.

6 percent, remains in the cake. The percentage yield of oil depends on the type or variety of flax and on the climatic conditions under which the crop is grown. If drought occurs when the seed is filling, that is, within a period of about 30 days after blossoming, the seed may be shrunken and the oil content low. High temperatures, which often accompany a period of drought, are especially injurious to flax, since they reduce the acre yield and the percentage of oil. In general, the large-seeded varieties yield a higher percentage of oil than do the small-seeded varieties. On the other hand, the small-seeded varieties may produce oils of a somewhat better drying quality, as indicated by a higher "iodine number." The iodine number is a chemical test which indicates the drying quality of the oil, or, more exactly, the quantity of oxygen the oil will absorb in drying to form the characteristic oil or paint film. Both the quantity and quality of the oil are influenced by the climate, especially by the amount of rainfall and the temperature under which the crop is grown.

HISTORY OF FLAX IN THE UNITED STATES

Flax grown for fiber was one of the first crops introduced from the Old World. In colonial times nearly every household had its patch of flax, and flax continued to be grown to some extent for home use as late as 1840. The manufacture of linseed oil was begun in the United States as early as 1805.

Until recent years flax has been a pioneer crop in the history of American agriculture, and the center of production has always been near the frontier. The census of 1850 showed Ohio and Kentucky to be the leading flaxseed-producing States, but by 1900 the center of production had shifted to North Dakota. During those 50 years the crop had migrated with the advance of settlement from Ohio, across Indiana, Illinois, Iowa, and Minnesota to North Dakota. This shift in areas of production was partly due to the injurious effect of flax wilt in the older cultivated lands, but chiefly to the economy of production on the fertile virgin soils of the middle Northwest.

In recent years the production of flaxseed in the United States has been insufficient to meet the requirements of domestic industries, and large quantities have been imported, chiefly from Argentina. The tariff act of 1930 provides a duty of 65 cents a bushel of 56 pounds on imported flaxseed and 4½ cents a pound on linseed oil. Under the previous tariff act (1922) the duty was 40 cents a bushel on flaxseed and 3.3 cents a pound on linseed oil. The annual production, net imports, and net supply of flaxseed in the United States from 1931 to 1940 are shown in figure 1.

THE FLAX-GROWING AREA

Flax is grown under a wide range of soil and climatic conditions but does best on the clay loam soils of the North Central States where the summer temperature is moderate and the rainfall adequate. The area of flaxseed production in 1939 is shown in figure 2. North Dakota, Minnesota, South Dakota, and Montana produce approximately 95 percent of all the flaxseed grown in the United States. In Minnesota and eastern North Dakota, the center of the flax-producing area, the rainfall ranges from 18 to 30 inches. The precipitation

diminishes westward to about 15 inches in eastern Montana. In the entire flax-producing area the crop depends largely upon the summer rainfall, and high yields depend on the amount and favorable distribution of precipitation.

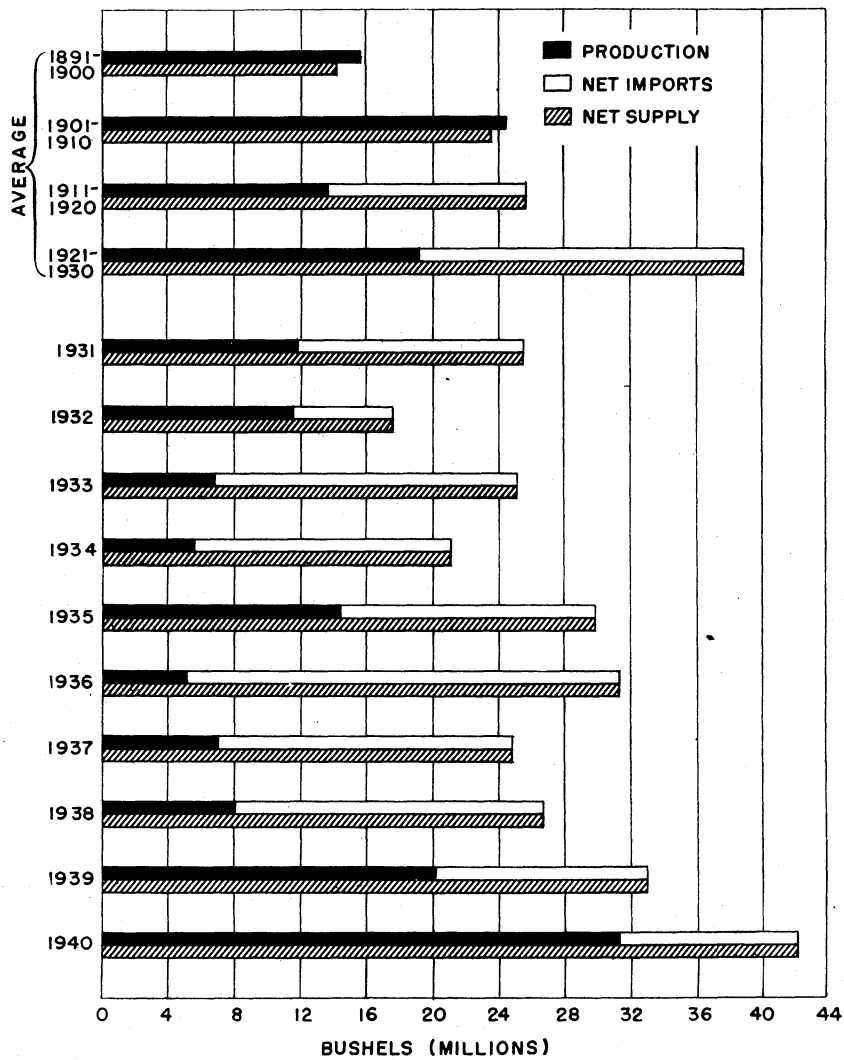

FIGURE 1.—Flaxseed production, net imports (including linseed oil in terms of seed), and net supply in the United States for the period from 1891 to 1940.

Under dry conditions flax has short, coarse straw and nonuniform fiber. Under such conditions the flax is of little value for fiber, and therefore only the highest yielding seed-flax varieties should be grown. In the principal flaxseed-producing area, where the annual rainfall is 25 to 30 inches, seed flax produces a fair quality of fiber suitable for those industries that heretofore have used imported flax tow and waste.

Flax is not a dependable crop in the dry-farming area of the central and southern Great Plains because of high summer temperatures and limited rainfall. In relatively cool, moist seasons it may yield well in that area. If flax is grown there it should be sown early so that it may make its growth before the hot weather of early summer comes on. Flax probably should not be sown unless there is a good supply of soil moisture at the time of seeding.

Flax is not well adapted to cultivation without irrigation in the western part of the United States, where the principal precipitation occurs during the fall and winter. Since flax is a spring-sown crop and matures late, the soil moisture stored from winter precipitation

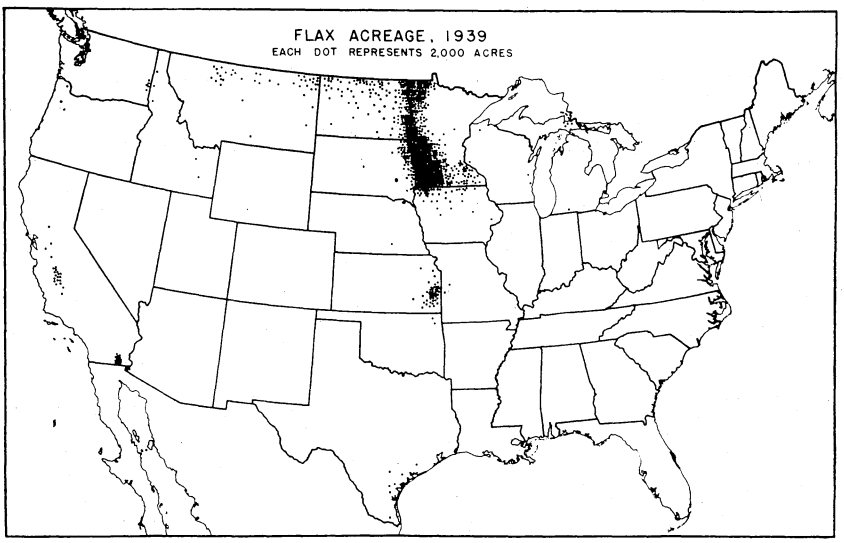

FIGURE 2.—Distribution of flaxseed production in 1939. Each dot represents 2,000 acres. Estimated area, 2,036,223 acres.

generally is insufficient to carry the growing crop through to full maturity. Flax is grown successfully under irrigation in the West and in the Southwest.

USES, MARKETS, AND MANUFACTURE

Flax is a cash crop, very little of it being consumed on the farm on which it is grown. The two commercial products of flaxseed are linseed oil and linseed meal. The former is used in the manufacture of paints and varnishes, linoleum, oilcloth, printer's ink, patent leather, imitation leather, and other products.

The principal markets for flaxseed are Minneapolis and Duluth, Minn. The linseed mills at Minneapolis consume the bulk of the flaxseed marketed there, whereas the seed received at Duluth is reshipped by way of the Great Lakes to mills at Chicago, Buffalo, Philadelphia, Edgewater, N. J., and in the vicinity of New York City. The eastern mills also crush imported flaxseed, chiefly from Argentina. Other linseed mills located at Red Wing, Minn., Sioux City and Des Moines, Iowa, Milwaukee, Wis., and Fredonia, Kans., crush the flax-

seed locally produced, while the mills at Portland, Oreg., and San Francisco and Los Angeles, Calif., use both domestic and imported flaxseed.

In the manufacture of linseed oil the flaxseed is ground to a fine meal by being passed through a battery of revolving steel rolls. The ground meal is then transferred to a steam-jacketed cylinder or "cooker," live steam being added if the meal is very dry, and heated to near the boiling point. This heating process facilitates the expression of the oil when the meal is subjected to pressure. After being heated, the meal is pressed firmly into a mold about 13 by 32 inches on a press cloth, which is folded over the cake. From 24 to 30 of these meal cakes are placed in a hydraulic press and subjected for about an hour to increasing pressure. The presses are operated in batteries of 6, the smaller mills having 12, 18, or 24 presses and the larger mills from 48 to 96 or more. The residue left after the oil is expressed is known as linseed cake, or, if ground, as linseed meal. The cake contains from 3 to 6 percent of oil, depending on the efficiency of the pressing.

A more modern type of press, known as the cage type, is efficient and economical of operation. The cage consists of a heavy steel cylinderlike drum about 6 feet high and oval in cross section, the walls being slotted to permit the escape of oil in pressing. The cage is filled with successive layers of ground flaxseed meal placed between press cloths and then subjected to hydraulic pressure by means of a heavy plunger. In another type of press, known as an expeller, the meal is fed into the machine and the oil expressed as a continuous process. This press is considered economical of labor but is somewhat less efficient than the presses described above in extracting the oil.

The extraction of linseed oil with naphtha, a solvent obtained from petroleum, was made use of to some extent a few years ago. This so-called "new process" was more effective than the pressing methods in extracting the oil from the ground flaxseed, leaving less than 2 percent in the meal. As the fire hazard was great and several mills were burned, the naphtha process has been discontinued in the United States. Moreover, livestock feeders generally prefer the ordinary "old process" linseed meal because of its higher oil content, which makes it mildly laxative and is believed to produce the glossy coats of animals to which it is fed.

VARIETIES OF FLAX

As already mentioned, there are two fairly distinct purposes for which flax is grown commercially, namely, fiber and linseed. The fiber flaxes are tall and early maturing and have small seeds. As flax for fiber is sown thickly, the stems are small and without basal branches. Fiber flax is never grown primarily for linseed; however, the seed that is not required for sowing the fiber crop is sold on the market for crushing.

The seed-flax or linseed group consists of several more or less distinct types: (1) Wilt-resistant, short-fiber flaxes; (2) common or so-called "Russian"; (3) Argentine; (4) Indian; (5) Abyssinian; (6) Golden or yellow-seeded; and (7) a few others of less commercial importance.

Nearly all varieties now grown commercially in the United States belong to the wilt-resistant, short-fiber type and have been developed by selection on the basis of wilt resistance and high seed yield. Linota, Buda, and Redwing belong to this group. These varieties are of mid-height, have small brown seeds, and are moderately wilt-resistant. They have, however, been replaced largely by Bison, which is exceptionally resistant to flax wilt.

Bison flax was developed by H. L. Bolley and his assistant, Ole Heggeness, at the North Dakota Agricultural Experiment Station, Fargo, N. Dak. Seed was first distributed to farmers in 1926, and by 1931 it had become the leading commercial variety in the United States. Bison has rather stout stems of midheight, medium to large brown seeds, and deep-blue flowers. The medium-large seeds of

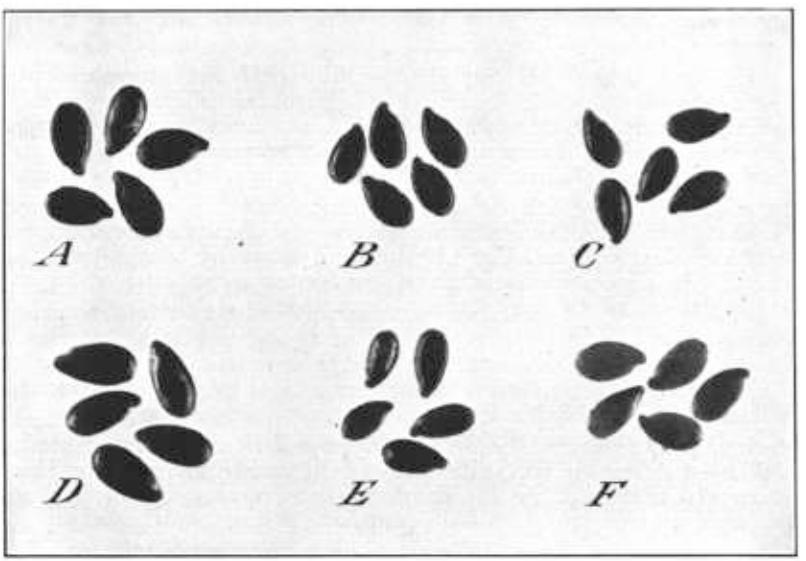

FIGURE 3.—Seeds of the principal commercial varieties of flax: *A*, Bison; *B*, Redwing; *C*, Linota; *D*, Argentine; *E*, Buda; and *F*, Bolley's Golden (C. I. 644). These seeds can be identified by their size, color, and shape. × 2.

Bison generally yield a higher percentage of oil than do the small-seeded varieties Buda, Linota, and Redwing.

Seeds of six important commercial varieties of flax are shown in figure 3.

Redwing, developed at the Minnesota Agricultural Experiment Station, is very early and moderately wilt-resistant and rarely lodges even when grown in rich soil. It can be distinguished in the field by its light-blue flowers. It has small brown seeds that yield an oil of good drying quality. It appears to be well adapted to southern Minnesota and Iowa and has proved to be a valuable variety where early maturity is required, as at Bozeman, in the Gallatin Valley of Montana, and at Edmonton, Alberta, Canada.

The common or "Russian" varieties formerly were grown extensively on new lands in the Dakotas, but owing to their susceptibility to wilt they have been largely replaced by wilt-resistant varieties.

Damont, Reserve, and Newland are varieties or strains selected from Russian N. D. No. 155. They are not wilt-resistant. Newland is grown in Montana, where flax wilt is rarely a problem. It is immune from rust.

The Argentine flax of commerce is not well adapted to the northern flax-producing area of the United States, where the growing season is comparatively short. In Argentina flax is sown in the fall or winter (May–July) and has a growing period of 5 or 6 months. As grown in Minnesota and the Dakotas, the plants of the Argentine variety generally are short, and in hot seasons many of the flowers blight and the bolls are poorly filled. Selected strains are more or less resistant to flax wilt, and most strains are immune from flax rust.

The Indian, Abyssinian, and Golden or yellow-seeded flaxes all are short and generally much-branched linseed types. As grown in Minnesota and North Dakota, they are usually too short to be harvested readily with the binder. Viking and Bolley Golden are grown commercially to a limited extent. These varieties have pale-pink flowers and large yellow seeds. Under favorable conditions they yield well and produce an oil of superior drying quality. The Indian and Abyssinian varieties have been grown occasionally by farmers in the North Central States but have never become established on a commercial scale.

GROWING THE CROP

PREPARING THE SEEDBED

Flax requires a firm seedbed. Poor stands often are due to seeding too deep in loose soil. Sod broken in the fall or spring should be packed by heavy rolling or by disking, harrowing, and rolling, and the surface should be made level before being seeded. Sod land should be prepared as soon as possible in the spring in order that the seed may be sown before the turned sod becomes dry. Where tractor outfits are used, plowing, disking, harrowing, packing, and seeding often are done in one operation. Pasture and meadow lands usually should be broken late in the summer. The rough sod will catch and hold the snow, frequent freezing and thawing will mellow the sod, and the land can be put in condition for early seeding.

A firm seedbed is as essential when flax is grown in rotation with other crops on old land as it is on sod land. For this reason corn ground usually is disked instead of plowed in preparation for flax. If spring plowing is necessary, the land should be made firm by rolling or disking, with the disks set nearly straight.

Whether fall or spring plowing of stubble land is best for flax depends on the conditions under which the crop is to be grown. In the humid area fall plowing and early spring seeding generally are considered best. In the drier areas the winter cover of stubble catches and holds the snow, which adds moisture to the soil. Under such conditions spring plowing may give the best results.

A firm, even seedbed permits the seed to be sown at a uniform depth. All harrowing should be done before seeding. Harrowing after the drill covers many seeds too deep and prevents the young plants from reaching the surface.

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METHOD OF SEEDING

Flax generally should be sown with a grain drill at a depth of about 1 inch. A drill with press attachments is most satisfactory, as it presses the moist soil around the seeds, thus insuring even germination. A soil packer that can be attached to any grain drill is shown in figure 4. When it is necessary to sow on loose soil, it is sometimes desirable to release the pressure springs on the drill and depend on the weight of the disks to place the seed at the proper depth.

In seeding wheat or other grain with flax, the two kinds of seed are mixed in the desired proportions at the granary and sown together about 1 inch deep. Usually alfalfa or clover is sown with a grass-

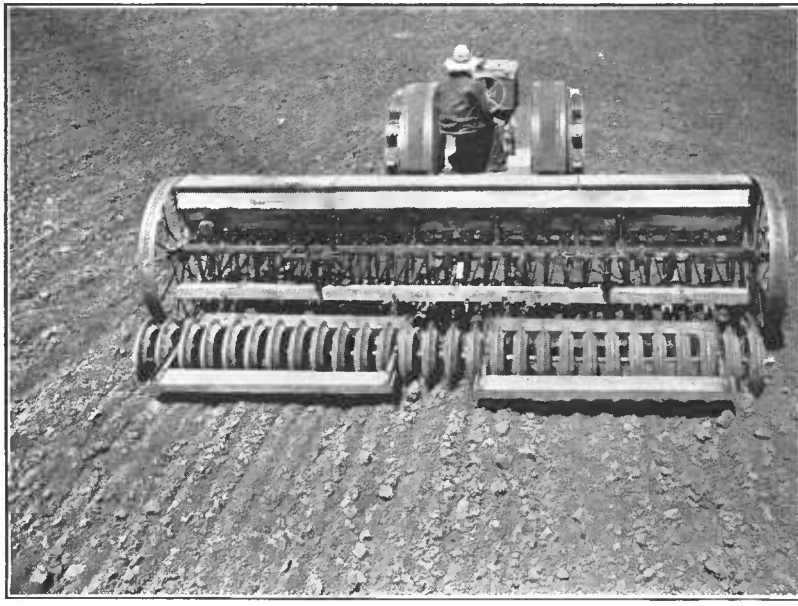

FIGURE 4.—A type of packer with wedge-shaped wheels designed to firm the soil and still leave the surface somewhat ridged to prevent soil blowing. The packer can be attached to any grain drill.

seeding attachment to the drill, although the seed of these plants can also be sown readily when mixed with flax.

TIME OF SEEDING

Formerly it was a common practice to seed flax late on sod land or as a catch crop on old land. This has led many growers to believe that flax should not be sown early. On the contrary, experiments show that early seeding generally produces higher yields. Early seeding allows the crop to make its growth during the cooler weather of spring and early summer, when it makes the most efficient use of the soil mixture.

Flax in the seedling stage is not easily injured by frost. Seedlings just emerging are most tender, but even these will endure a moderate frost, especially if the soil is moist and they are not further injured by drying winds. After the plants are 2 or 3 inches high and are hard-

cned by exposure they will endure a temperature of 20° to 22° F. for a short time without injury. The degree of injury is dependent on the minimum temperature, the condition of the plants, the soil moisture supply, and the weather conditions after freezing.

Flax in the green-boll stage is readily injured by heavy frosts, which may occur late in the summer or at high altitudes. The green seeds, which contain from 50 to 75 percent of moisture, are killed by freezing temperatures, although the leaves and stems of the plants may not be injured. The writers have seen fields of green flax that

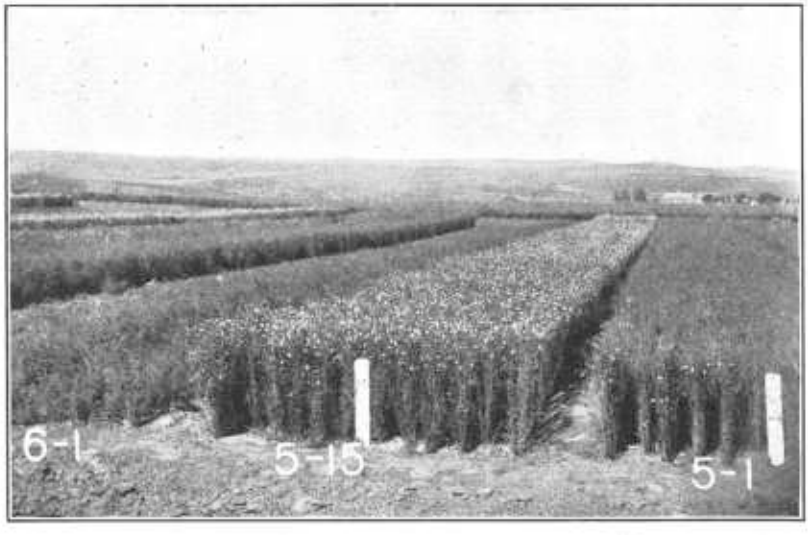

FIGURE 5.—Plots of flax sown at intervals of 15 days from May 1 to June 1, at Mandan, N. Dak. The plot sown on May 15 was in full bloom when photographed on July 7, 53 days after being seeded.

appeared quite normal, but on examination the seeds were found to be shrunken, worthless, and dead.

Experiments in the northern Great Plains area indicate that flax sown during the first part of May usually produces the highest yield. For best development flax requires cool weather at the time of blossoming and ample moisture until ripening begins. Such conditions are most likely to prevail at blossoming time if the seed is sown early. Flax may be sown during the first week of June, however, with fair assurance that it will ripen before frost. Later seeding often results in low yields, even though the crop escapes frost. Plots of flax sown at intervals of 15 days from May 1 to June 1, at Mandan, N. Dak., are shown in figure 5.

It often is an advantage, especially where Russian-thistles, wild oats, and other early weeds are abundant, to cultivate the land with a field cultivator, disk, or harrow in order to germinate seeds and to destroy the weeds before seeding flax. On the other hand, where late weeds, such as green and yellow foxtail (pigeon grass), are bad, flax should be sown early so that it may become established before these warm-weather weeds get started. A good stand of early-sown flax is effective in the control of weeds, as is shown in figure 6.

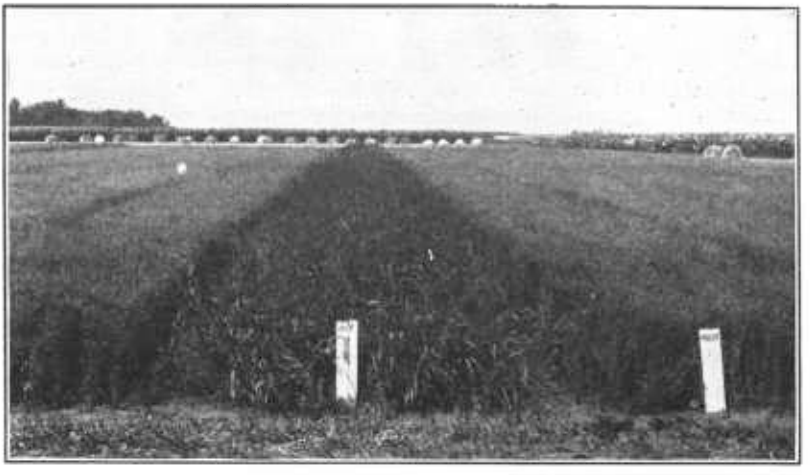

FIGURE 6.—A plot of Damont flax (middle) destroyed by wilt and grown up to weeds, chiefly green and yellow foxtail. The wilt-resistant varieties on each side have maintained good stands, which checked the growth of weeds. Photographed July 30 at the North Dakota Agricultural Experiment Station.

RATE OF SEEDING

In Montana and the Dakotas the usual rate of seeding for flax is 2 pecks (28 pounds) an acre, while in eastern Minnesota, where the rainfall is greater, it is considered an advantage to seed 3 pecks (42 pounds). The heavier rate of seeding insures a fuller stand and may help to control weeds. Under irrigation, flax usually is sown at the rate of fully 3 pecks an acre.

FIGURE 7.—Seed flax being harvested with a grain binder and put up in narrow shocks to dry.

The rates of seeding mentioned are recommended for Bison flax, which has medium-sized seeds. If a small-seeded variety is grown, the rate may be slightly reduced, whereas for a larger-seeded type, such as Argentine, the rate probably should be somewhat increased.

HARVESTING

The flax plants should be fully ripe when cut, unless unusual conditions make this impracticable. Fully ripe flax will dry quickly in the shock or bunch. If sown late, or if the fall season is wet and cool, flax may continue to bloom until frost. Under these conditions it may be advisable to cut the crop when a large proportion of the bolls are ripe, even though the stems are still green.

Flax generally is cut with a grain binder. By proper adjustment, bundles of fair size and shape can be made. When flax cut with a binder is shocked the bolls are kept from the damp ground and the seed is not damaged. Small shocks should be made so as to allow ventilation through the center, or the bundles should be placed in long shocks only two bundles wide (fig. 7).

In the drier area flax sometimes is cut with a header or a reaper. The use of the reaper or the header saves the expense of twine and the labor of shocking. The small loose bunches dropped by a reaper or by a header with buncher attachment dry out rapidly in clear weather. Following a heavy rain, however, the bunches should be turned to dry; otherwise much seed will be damaged.

The cost of harvesting flax has been materially reduced by the use of the combine. Three more or less distinct methods of combine harvesting—windrowing, direct combining, or delayed harvesting—can be used, depending upon the condition of the crop.

If the flax crop is weedy, the use of the windrower is recommended. In dry weather, a few days after cutting, the windrowed flax will be in condition to thresh. Occasionally there is some difficulty in picking up windrowed flax if it settles down in weedy fields. To avoid this it is desirable to thresh the crop as soon as it is dry. In certain years flax does not ripen readily because of damp, cool weather, and in such seasons the use of the windrower is necessary. The windrower method is very generally used in harvesting flax on farms where the combine is available. It is cheaper than binding and is fully as satisfactory. The operation of the windrower costs about 50 cents an acre.

When the crop is free from weeds and has ripened uniformly, direct combining is the cheapest method and under favorable conditions is entirely satisfactory. Direct combining should not be attempted unless the flax is thoroughly dry and free of weeds.

In Montana and North Dakota harvesting sometimes is delayed until frost has killed the weeds. The weeds dry up rapidly after being frozen, and the flax can be harvested with a combine in a few days after frost. Ordinarily, flax will stand for a considerable time after ripening without loss from shattering. In very dry, hot weather, however, it may shatter somewhat, and therefore delayed harvesting can be recommended only when late flax does not need to stand too long before frost.

The combine or the windrower can often be used to harvest flax that is too short to be cut with a grain binder. This advantage in the use of the combine, however, does not justify the growing of short varieties of flax that are more difficult to harvest by all methods.

ROTATION

Formerly the bulk of the flax crop was raised on newly broken sod. Flax is well adapted to growing on prairie sod while the sod is rotting. It has the further advantage of being a quick-growing crop, requiring generally from 90 to 110 days from seeding to ripening. In the northern Great Plains flax can be sown as late as the first week of June with fair assurance of ripening, although early seeding generally is to be recommended.

Flax grown in rotation on old land should follow a crop that will free the land of weeds and leave a firm seedbed. A good rotation for flax is one that includes a legume crop such as sweetclover, red clover, soybeans, field peas, or alfalfa, followed by a cultivated crop like corn. Such a rotation should provide a fertile soil, clean land, and a firm seedbed.

Experience and experiments both indicate that flax does well when it follows corn. Where cultivation has kept the weeds under control, flax following corn has invariably given satisfactory yields in the flax-growing area. The usual practice is to sow the flax in the corn stubble without plowing. Where there is sufficient moisture and care is taken in the preparation of the seedbed, flax may also be grown following a legume crop. In rotation experiments at Fargo, in eastern North Dakota, flax has yielded better following red clover than following sweetclover, timothy, or alfalfa. In these tests the clover, alfalfa, or timothy was cut for hay, and the land was fall-plowed. Alfalfa growing on the land for several years depletes the supply of soil moisture. Therefore, flax crops following alfalfa were usually injured by drought in years of low rainfall. Sweetclover, like alfalfa, is a heavy user of water and leaves the soil very dry. The succeeding crop is therefore dependent on a fairly constant and generous supply of summer rain. Under conditions of limited or uncertain rainfall it would be preferable to have flax follow corn. If desired, the corn may be preceded by a legume crop or a legume-grass mixed crop in the rotation.

Experiments carried on by the Minnesota Agricultural Experiment Station, in which flax in 1923 followed several crops that had been grown for 2 years in succession (1921 and 1922) on the same plots, gave interesting results. Arny[2] says:

> The results from this work indicate that flax following corn produced the best crop. Flax following red clover, sweetclover, soybeans, and field peas was nearly as good as that following corn. Flax following wheat, oats, barley, rye, buckwheat, and flax was second rate as compared with that following corn, and flax following millet and sorghum was practically a failure. Flax following timothy was third rate.

In semihumid areas where alfalfa, clover, or grass is included in the rotation, flax can be used successfully as a nurse crop. Since it does not produce dense shade, it makes a better nurse crop than do the cereal crops, which produce a ranker growth.

CONTROL OF WEEDS

Because the flax plant is a poor weed fighter, it should be grown on the cleanest land available. Newly turned sod of prairie, pasture, and meadow lands having clover or other legume and clean corn stubble are best for flax.

[2] ARNY, A. C. GROWING FLAX AS A REGULAR FARM CROP. Oil, Paint and Drug Reporter. 104(20): 49. 1923.

Where old ground is used, every effort should be made to get rid of weeds and weed seeds before seeding. It often is an advantage to disk the land early in the spring to help start the growth of weeds. After 10 days this land may be disked or cultivated again to destroy the sprouting weeds. If there are many unsprouted weed seeds in the soil it may be advisable to delay seeding for still another 10 days in order to allow these to germinate and make possible their destruction by further cultivation just before seeding. Early-sown flax is preferable to late-sown flax; therefore delayed seeding, with cultivation, should be regarded mainly as a means to reduce weed competition. The object is to destroy weeds and weed seeds and still sow the flax as early as possible.

Control practices will vary to some extent with the kind of weeds. Where late weeds, such as green and yellow foxtail (pigeon grass), are troublesome, flax preferably should be sown early, so that it may become well established before these weeds begin growth. Early-sown flax usually will ripen before green foxtail, and the immature weed seeds may be separated from the flax in recleaning by the use of a strong air blast.

Ordinarily, flax does not do well on loose soils following potatoes, especially on old lands that are likely to be foul with weed seeds. Since in the usual potato-digging operations buried weed seeds are brought to the surface, where they germinate readily the following spring, it generally is better to follow potatoes with a more vigorously growing crop. Moreover, the loose soils of potato fields are not very desirable for flax unless well firmed before sowing.

In the northern Great Plains, flax after summer-fallow is not always successful, although the reserve moisture supply in a well-kept summer-fallow is very beneficial to the succeeding crop. Even if weeds are kept under control during the season of summer-fallow, there is no assurance that such a field will be free from weeds. Russian-thistles and other weeds blown in from nearby fields during the fall and winter may reseed an otherwise clean seedbed. Wheat, a more vigorous crop than flax, is commonly grown on summer-fallowed land.

Where Russian-thistles are prevalent in corn stubble, it is an advantage to disk the land a few days before seeding to promote the germination of weed seeds and then harrow just before seeding to kill the young weeds. In the northern Great Plains it is a common practice to leave wheat stubble unplowed until spring in order to hold the winter snow. Such land can be plowed shallow and the soil settled by use of a cultipacker or similar implement in preparation for flax. As an occasional emergency practice, burning wheat stubble is a cheap and effective method of preparation for flax. Although the burning of wheat stubble cannot be recommended as a general practice, it has an advantage in the elimination or control of Russian-thistles and perhaps also in the destruction of newly hatched grasshoppers. Flax can be sown directly on clean burned land, or the land can be disked lightly or cultivated with a spring-tooth harrow to prevent soil blowing. Probably burning should not be done, nor flax sown, unless the soil is moist to a depth of 15 to 18 inches as a partial insurance against drought. If the soil is dry at seeding time, there is little or no chance of making a profitable flax crop.

It is not easy to eliminate or control weeds in flax fields, and therefore fields that are known to be very weedy should not be sown to

flax. Some weeds, as already stated, can be checked by tillage before seeding; however, this causes some delay in seeding. The late warm-weather weeds can be controlled by early seeding, which permits the flax to get well established before such weeds begin growth. A knowledge of the growth habits of different weeds is of first importance

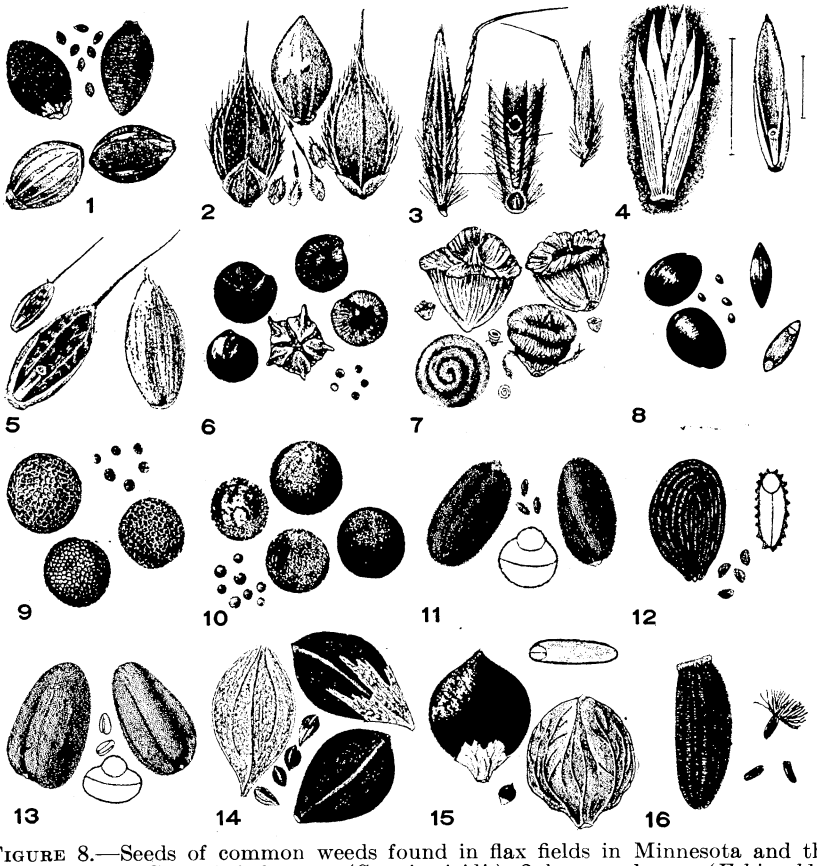

FIGURE 8.—Seeds of common weeds found in flax fields in Minnesota and the Dakotas: 1, Green bristle grass (*Setaria viridis*); 2, barnyard grass (*Echinochloa crusgalli*); 3, wild oats (*Avena fatua*); 4, quackgrass (*Agropyron repens*); 5, darnel (*Lolium temulentum*); 6, lambsquarters (*Chenopodium album*); 7, Russian-thistle (*Salsola pestifer*); 8, redroot pigweed (*Amaranthus retroflexus*); 9, Indian mustard (*Brassica juncea*); 10, wild mustard (*Brassica arvensis*); 11, hares-ear-mustard (*Conringia orientalis*); 12, French weed (*Thlaspi arvense*); 13, falseflax (*Camelina sativa*); 14, wild buckwheat (*Polygonum convolvulus*); 15, Pennsylvania smartweed (*Polygonum pennsylvanicum*); 16, perennial sow-thistle (*Sonchus arvensis*). Natural size and enlarged. Drawings by F. H. Hillman.

in planning a proper method of control. In figure 8 are shown weed seeds that are most commonly found in flax in Minnesota and the Dakotas.

These weed seeds are objectionable in flaxseed because many of them absorb oil in the crushing process and therefore reduce the total yield of oil. Mustard seeds, on the other hand, yield oil in crushing, but it is not a drying oil. If present in large quantity this oil is

objectionable because it lowers the drying quality of the linseed oil. All these weed seeds should be removed from flaxseed that is to be used for seeding. Perennial sowthistle and quackgrass are serious weed pests and flaxseed should be carefully examined to avoid them.

FLAX AND WHEAT AS A MIXED CROP

Flax in mixture with spring wheat is grown to some extent in Goodhue County, Minn., and the surrounding district. The chief advantages of the mixed crop over flax grown alone appear to be (1) the greater ease of handling in harvesting and threshing, (2) the better control of weeds, and (3) a possible greater total return per acre. The mixed crop is sown at the usual date for seeding spring wheat. The usual rate of seeding in southeastern Minnesota is 25 to 40 pounds of flax with 2 or 3 pecks of wheat per acre.

Flax sometimes is sown in fields of winter wheat where the stand has been thinned by winter-killing. This is successful if the fields are not too weedy. If weeds are numerous or the stand of wheat too thin, it probably would be best to disk or plow the field before seeding to flax or other crop. Peppergrass (*Lepidium*) and other annual winter weeds grow rapidly in badly winter-killed wheat fields and will choke out flax.

FLAX UNDER IRRIGATION

Flax is grown under irrigation only to a limited extent, although experiments indicate that it responds well to irrigation. It should be grown in a rotation that will free the land of weeds and maintain a high state of fertility, especially readily available nitrogen. At the Huntley (Mont.) Field Station flax has been grown in a 6-year rotation of alfalfa (3 years), corn, flax, and sugar beets. The alfalfa of the third season and the corn are pastured to pigs (hogged off), thus leaving the residue of two crops on the land. The average yield of flax for a period of 22 years has been 24.6 bushels an acre. The yield of sugar beets following flax has been high (an average of 15.6 tons an acre), indicating that flax has no injurious effect on the yield of sugar beets.

Yields of 20 to 40 bushels an acre have been obtained in varietal experiments at the Montana Agricultural Experiment Station at Bozeman, where conditions are favorable for flax. The crop was grown on clean summer-fallow and given only one irrigation at the beginning of the blossoming period. Possibly such high yields cannot be expected on a farm scale, but they indicate that flax responds well to irrigation.

At Brooks, Alberta, Canada,[3] the water requirement of flax grown in field plots under irrigation in 1920 and 1921 was determined. The use of 0.85 acre-foot of water applied in 4-inch irrigations was required to produce a 10-bushel acre yield of flax; 1.1 acre-feet produced 15 bushels; 1.25 acre-feet produced 18.5 bushels; 1.3 acre-feet produced 20 bushels; and a maximum yield of 21.5 bushels per acre required 1.34 acre-feet of water.

Since flax is a comparatively shallow-rooted crop, it responds better to light irrigations. This is illustrated by the fact that it required 5½ acre-inches more water to produce 18.5 bushels per acre in 6-inch than in 4-inch irrigations.

[3] Irrigation Practice and Water Requirements for Crops in Alberta. Canada Dept. Int., Reclam. Serv. Irrig. Ser. Bul. 6. 1922.

Under irrigation, flax usually is sown at a rate of 45 pounds per acre. It is desirable to seed early, so that the crop may have a long growing season. When the crop begins to ripen it is desirable to withhold irrigation in order to hasten maturity; if the soil is kept wet, blooming may continue indefinitely.

USES FOR FLAX STRAW

Heretofore there has been a limited market for flax straw in the manufacture of upholstery tow, insulating material, rugs, twine, and paper. Recently a new industry—the processing of fiber from flax straw for manufacture of cigarette paper and other high-grade papers—has been developed by commercial interests. This new mar-

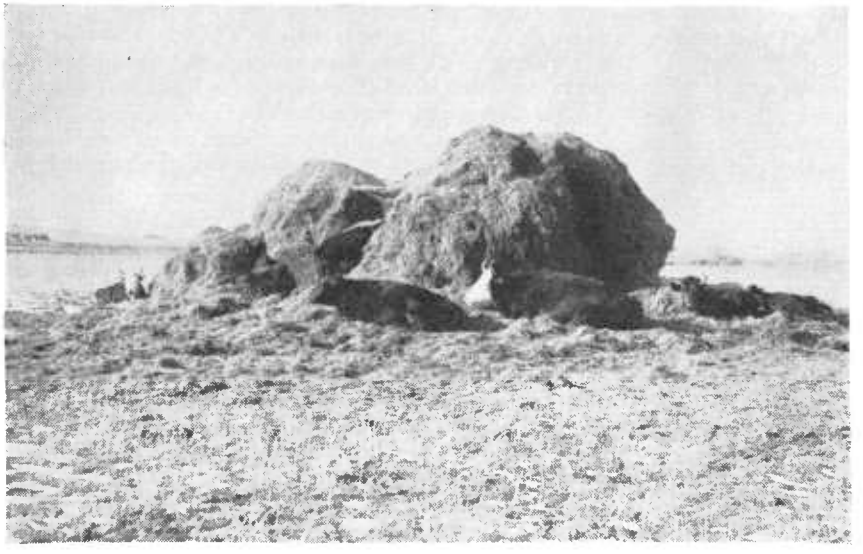

FIGURE 9.—Cattle eating and bedding on a stack of flax straw.

ket for straw has furnished flax growers in California and Minnesota with an additional income from the flax crop. Previous to the present war emergency, most of the cigarette paper was imported from Europe.

For economy of processing, flax straw must be available in considerable quantity, and it must be relatively free from weeds. Weedy flax and short flax from the drier areas are not considered suitable for processing. Little is known about the quality of fiber of different seed flax varieties, but it is probable that weather and growing conditions are more important than variety in determining the yield and the quality of the fiber.

The total yield of straw from experimental plots, where all the straw is recovered, ranges from about ½ ton an acre in the drier areas of the northern Great Plains to 2 tons or more under irrigation in California, Idaho, and Montana. A straw yield, including chaff and leaves, of ¾ to 1¼ tons an acre may be considered about the average on farms in Minnesota. In the drier sections the yield of clean straw, free of chaff and leaves, is but little greater than the yield of seed in pounds per acre.

In most localities flax straw is sold under contract with processing plants or through cooperative organizations. A recent development is the use of portable machines that extract the fiber at the farm, thus reducing the cost of baling and transportation to the central processing plant. The income from flax straw is small as compared with that from the seed, but farmers usually get from $1 to $2 a ton for straw in the stack, in addition to wages for baling and hauling to the processing plant or shipping point. This new industry makes use of a product that formerly was largely wasted (fig. 9).

CLEANING AND STORING THE SEED

Hundreds of cars of flaxseed are shipped to market that contain from 10 to 40 percent of dockage. This dockage often consists of cracked flax, weed seeds, and grain, which are valuable for feeding. These should be screened from the flaxseed and ground and fed on the farm, since the grower receives little or no pay when they are marketed as dockage. Screenings should be finely ground so that weed seeds will not be scattered about the farm.

Flaxseed should be thoroughly recleaned with a good fanning mill before being sown. A steel-wire sieve with meshes 4 by 16 per inch (or 4 by 14 for large-seeded varieties) will separate grain and the larger weed seeds from flax. A metal sieve with round holes one-fourteenth of an inch in diameter will separate small weed seeds. The air blast should be regulated so as to blow out all immature and cracked flaxseeds and trash.

Flax intended for seed should be recleaned before being stored, and only dry, sound, plump seed should be saved. This will reduce the development of wilt, rust, and other diseases that may be carried as spores on the broken stems, chaff, and immature seeds. Flaxseed should be dry and should be stored only in a dry place. Air-dry flaxseed contains only 6 to 8 percent of moisture, depending upon the humidity of the atmosphere.

DISEASES OF FLAX

The principal diseases of flax are wilt, rust, heat canker, and pasmo.

WILT

Wilt is a fungus disease that may attack flax plants at all stages of growth, causing them to wilt and die. It grows upon the live plant and upon the dead roots and stems in the soil. When once introduced, therefore, it may remain in the soil for an indefinite period. Figure 10 shows the first appearance of wilt in a field frequently cropped to flax. In many cases such spots of wilt appear in the second or third crop. Authentic cases are known where a crop of flax was grown on new land without noticeable loss from wilt, but on the same land 5 years later the crop was entirely destroyed by wilt. The fungus apparently was introduced into the soil with seed for the first crop and increased during the 5-year period until it was widely distributed throughout the soil.

Wilt usually is introduced into a clean soil by sowing infected seed, although wind-blown soil and trash or run-off water from infected fields may carry the wilt fungus to new lands.

The use of mature, well-cleaned seed and the treatment of the seed with a copper carbonate or some other good dust fungicide should prevent or at least delay the introduction and spread of the flax wilt fungus to new lands. Although it is very desirable to prevent the introduction of wilt on new land as long as possible, the most prac-

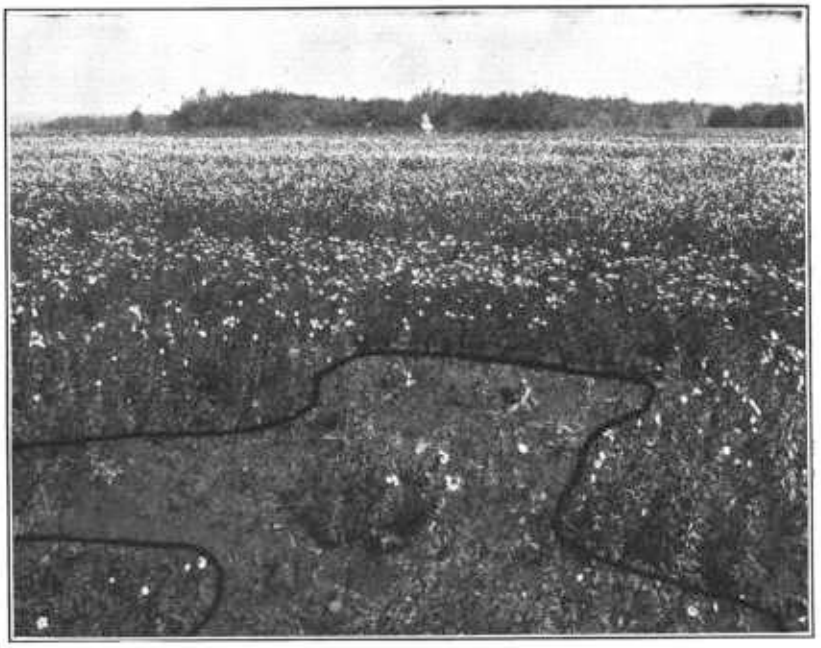

FIGURE 10.—A field frequently cropped to flax, showing the first appearance of flax wilt in spots. A wilt-resistant variety, such as Bison, can be grown on such land without loss from wilt.

FIGURE 11.—A flax-breeding nursery showing the wilt resistance of selected strains of flax in contrast to the total loss of susceptible varieties. Photograph taken on "flax sick" soil at the North Dakota Agricultural Experiment Station.

ticable method of control is to grow a wilt-resistant variety (fig. 11). The wilt-resistant varieties Bison, Buda, Linota, and Redwing are generally grown.

RUST

In wet seasons or on low, damp soils rust may do considerable damage to flax, especially if the crop is late in ripening. The disease appears as bright orange pustules on the leaves and green stems. Later in the season the spots turn darker because of the appearance of the brownish spores that overwinter on the straw. As new infection comes from the old straw and stubble of the previous year, a rotation that avoids putting flax on the same land 2 years in succession will help to control this disease. A few varieties are immune from rust. These include most strains of Argentine, a few strains of Indian, Newland, Ottawa 770B, Cirrus, a fiber flax, and a group of hybrid strains. The most promising method of control appears to be the breeding of varieties resistant to both wilt and rust.

HEAT CANKER

Heat canker is caused by high temperature at the surface of the soil and usually occurs when the plants are from 2 to 6 inches high. It is most destructive on soils that have been compacted by rain. The stems are girdled and the plants break over. Some plants may continue to grow for a time, but ultimately they break off in the wind. The best control measure appears to be early seeding at a rate sufficient to insure a full stand. This enables the plants to become large enough to shade the ground somewhat before the hot weather of late June and early July.

PASMO

Pasmo first appears as yellow-brown circular lesions on the seed leaves (cotyledons) and foliage of young flax plants. However, it is most readily recognized on the flax stems in the early ripening stage as irregular bands of brown mottling alternating with bands of green. It is not known how much damage pasmo causes. Fair yields of seed are obtained when the disease appears to be prevalent. It probably does more damage to fiber flax than to seed flax. Argentine varieties appear to be more susceptible to the disease than others. Pasmo is known to be carried on the seed; the introduction of infected seed into new territory should be avoided so far as possible.

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